

D-4 ECOLOGY AND BEHAVIOR OF COLUMBIA RIVER SALMONIDS

4.1 Salmonids In Highly Modified River

The lower Columbia River and its estuary are part of a highly modified river system. The modifications have resulted in a number of the salmon stocks being officially listed as threatened or endangered under the Endangered Species Act (ESA). Modifications began during the 1860s and 1870s when commercial fishing became sufficiently intense to essentially eliminate some stocks of salmon (Gilbert and Evermann, 1894). Subsequent modifications to the physical and biological characteristics of the river basin have resulted in the official listing of 14 evolutionarily significant units (ESUs) and distinct population segments (DPSs), or species for the Columbia River. These alterations and their potential impacts were identified in R. M. Thom's white paper (2001) on a conceptual model for the Columbia River Navigation Channel Improvements Project (the Project).

Thom's white paper identifies 14 species of concern and presents information describing their basic habitat needs during the periods they occupy the lower Columbia River in the area potentially affected by the channel deepening project. A brief description of the species (ESUs and DPSs) is followed by a summary of information describing the habitat characteristics identified in the existing literature as important to the life stages of ESUs and DPSs as they move through the lower Columbia River and similar areas of the Pacific Northwest.

Nearly all the information available to describe the biological processes related to listed species in the Columbia River was obtained after the river system's biological and physical characteristics had been highly modified. Thus, our understanding of how the system functions is derived from this modified system. We have only inferential logic and sketchy information to describe how the river system most likely functioned naturally before it was modified.

In the following discussion, the term "salmon" refers to various life stages of the chinook, chum sockeye, and steelhead ESUs and DPSs. The term "salmonid" refers to each of these salmon ESUs as well as the anadromous forms of the cutthroat trout and bull trout DPSs.

4.1.1 Objective

The purpose of this document is to describe the known biological characteristics of the listed species pertinent to the action area and the proposed Project.

The discussion in this paper is restricted to information describing biological processes only in the project area, other than a brief description of each ESUs spawning and rearing areas, and how they influence timing and habitat use within the project area. The information provided has been developed both from the lower Columbia River and from other Pacific Northwest estuarine areas that support the fish species listed in the project area. The assembled information is appropriate for interpretation of potential impacts of the proposed navigation channel deepening project on listed species. This purpose of this information is twofold: (1) to help avoid impacts to habitat supporting listed species, and (2) to potentially identify how the project can support recovery of the species.

4.1.2 Habitat Conditions In Project Area

The Project encompasses an area that essentially all juvenile salmon and returning adults use as a migratory corridor. Their use of habitat within the action area varies with life stage and species, primarily related to size of the fish when they migrate through the action area.

Juvenile rearing and migrations

Young salmon are likely present in at least small numbers through out the year; however, substantial numbers of juveniles first appear in the project area in middle to late March. These young chinook and chum are fish produced in the lower river area, including tributaries within the Bonneville Dam area and possibly within the Willamette River basin. Commonly these very young chinook and chum are the smallest migrants passing through the project area. Other subyearling chinook migrating later in the year from upstream locations tend to be somewhat larger, with the largest subyearlings reaching the lower river from the upstream reaches in the autumn. Consequently, several different size groups of sub-yearling salmon that account for some juveniles in the lower Columbia River appear in substantial numbers from March through about October.

Smaller juvenile salmon tend to rear and move relatively slowly through the lower river, primarily in shallow water habitat. Older subyearlings and smolts tend to move faster through the lower river, with less dependence on shallow water habitat; they also tend to be surface-oriented.

Juvenile cutthroat and bull trout are present within the Columbia River estuary during the spring and early summer at the same time as the young salmon. However, the young trout tend to be the size of salmon smolts and larger. These fish are relatively rare in fish collections; therefore information on their habitat requirements in the lower Columbia River is limited.

Adult migrations

Adult salmon return through the lower Columbia River from early spring through early autumn. Spring chinook begin entering the lower river in March or April, with the majority moving through the area in middle to late April or early May. They are sequentially followed by summer chinook and fall chinook, with chum, steelhead, and cutthroat and bull trout moving upstream during the same general period. During their upstream migrations through estuaries and lower rivers, the adult salmon are not oriented to any specific habitats. They generally tend to remain relatively close to the surface but also use greater depths at times. The National Marine Fisheries Service (NMFS) has designated two basic reproductive ecotypes of steelhead, depending on the time they migrate upstream—ocean-type (winter run) and stream-type (summer run). Stream-maturing steelhead enter the lower river in a sexually immature condition, requiring several months of residence within the river prior to spawning.

4.2 ESUs and DPSs

The listed species (ESUs and DPSs) shown in Table D4-1 pass through the lower Columbia River both as juvenile downstream migrants and as sub-adults or adults on return migrations. Some individuals of the steelhead, cutthroat, and bull trout species may pass through the lower Columbia River more than once because they survive to spawn more than one time.

Table D4-1: Listed ESUs and DPSs for the Columbia River System

SPECIES (Evolutionarily Significant Unit)	STATUS	JUVENILE LIFE STATE IN PROJECT AREA	DATE LISTED
CHINOOK			
Snake River spring/summer	Threatened	Yearling	April 22, 1992
Snake River fall	Threatened	Subyearling	April 22, 1992
Lower Columbia River	Threatened	Subyearling	March 24, 1999
Upper Columbia River spring	Endangered	Yearling	March 24, 1999
Upper Willamette River	Threatened	Yearling	March 24, 1999
SOCKEYE			
Snake River	Endangered	Smolt	November 20, 1991
STEELHEAD			
Snake River	Threatened	Smolt	August 18, 1997
Lower Columbia River	Threatened	Smolt	March 19, 1998
Middle Columbia River	Threatened	Smolt	March 25, 1999
Upper Columbia River	Endangered	Smolt	August 18, 1997
Upper Willamette River	Threatened	Smolt	March 25, 1999
CHUM			
Columbia River	Threatened	Subyearling	March 25, 1999
BULL TROUT			
Columbia River	Threatened	Smolt or larger	June 10, 1998
CUTTHROAT TROUT			
Southwestern Washington/Columbia River	Threatened	Smolt or larger	October 25, 1999

4.3 Three Guilds of Columbia River ESUs

Each of the Columbia River ESUs and DPSs has some unique life history characteristics that help to separate it from adjacent populations of the same species. However, for consideration of the Project, these ESUs and DPSs can be aggregated into several general life history types. The salmon tend to follow one of two life history types—ocean type and stream type—that provide different size fish with substantially different habitat requirements. A portion of the cutthroat and bull trout populations are anadromous and follow a third life history form, as do some wild steelhead. Characteristics of each of the life history types are listed below.

Ocean type

- Rear only weeks to months in fresh water
- Are small (30 to 80 centimeters [cm])
- Use shallow water/shoreline habitat (0.1 to 2 meters deep, current less than 0.3 meters per second)
- Prolonged rearing in lower river (weeks to months)
- Include fall chinook, chum, and pink (few listed)

Stream type

- Rear more than 1 year in fresh water prior to downstream migration
- Are large (10 to 30 cm or larger)
- Generally move in open water
- Move relatively quickly through lower river (days to weeks)
- Include spring chinook, coho, sockeye, steelhead, bull trout, and cutthroat trout

Trout

- Rear 2 to 3 years in fresh water streams
- Migrate as very large juveniles (14 to 30 cm) or as adults
- Rear throughout the late spring and summer in estuarine or ocean areas
- Are scarce in scientific collections, which implies they are not commonly found in shallow water habitats or are adept at escaping sampling gear

A question raised during this process was whether or not the 14 ESUs and DPSs can be grouped into guilds or if they require individual species analyses. The first step in answering this question is to identify a common definition of a guild. The guild concept was defined by Root (1967):

“A guild is defined as a group of species that exploit the same class of environmental resources in a similar way.”

According to Jaksi (1981), the term guild should be reserved for co-occurring, interacting species in a particular habitat. The salmonid ESUs and DPSs in the Columbia River fit this requirement for at least a portion of their life cycles.

In the lower Columbia River and its estuary, several general classes of environmental resources are exploited or used by salmon, including:

- Shallow water (less than 6 feet deep) beaches and tideflats composed of fine-grained sediment, and having low current velocities (less than 0.3 foot per second)
- Near surface (within 20 feet of surface) water column areas not associated with specific substrate types or specific current velocities
- The entire water column

Because various members of the ocean-type and stream-type groups tend to use the lower river's environmental resources in a similar way, they tend to fit the definition of a guild.

Ocean-type salmon fry migrate through the lower estuary slowly, remaining in shallow water most of the time. These small fish undergo a rearing migration that provides substantial growth prior to their entry into ocean conditions. In the lower river, ocean-type chinook are present as several different size groups ranging from small fry [~35 millimeters (mm)] to much larger late summer migrants (~80 to 100 mm).

Stream-type salmon migrate relatively rapidly through the lower river and estuary in a directed migration that takes only days to weeks. During this migration, they remain surface oriented but occupy a greater depth range and areas of higher current velocity than do the smaller ocean-type fish. These larger juveniles tend to be water-column-oriented rather than substrate-oriented like the smaller ocean-type

juveniles. Because of their larger size, the stream-type juveniles are generally ready to meet ocean conditions by the time they enter the project area.

Adult and sub-adult salmon form a separate guild. Adult fish, which include the chinook, steelhead, and sockeye ESUs and DPSs enter the project area on their upstream migration as sexually maturing fish nearly ready to spawn. These fish generally have ceased feeding by the time they enter estuarine areas. The adults actively swim within the water column, occupying a wide range of depths but commonly within about 50 feet of the surface. At times the adult salmon are found near the bottom, but do not appear to use the substrate in any specific manner. Adults appear to be consistently milling or actively migrating.

Anadromous trout juveniles and adults may rear within the estuary; however, little factual information is available to document this occurrence. Apparently their numbers are sufficiently small and their capacity to avoid sampling gear is sufficiently great that little information data has been generated regarding the characteristics of the estuarine habitat they use. Brown (1992), Kraemer (1994), and Smith and Slaney (1980) provide what information is known about the anadromous form of bull trout. Most juveniles migrate at 2 to 3 years of age. Surviving anadromous adults also migrate back to saline conditions following spawning to undergo additional rearing in the saline environment. Downstream migration occurs during the spring, with rearing in either the estuary or the ocean during the summer, and return migration in the autumn. Some adults return upstream as early as April in some streams, migrating much as adult salmon with little or no feeding. Cutthroat trout appear to have similar life-history characteristics. Sumner (1962), Lowry (1965), Giger (1972), and Johnson (1981) provide information on the life history characteristics of the anadromous form of coastal cutthroat trout. Most migrate to the estuary or ocean during the spring for several months of rearing, returning to their natal streams as sub-adults or adults. These trout may migrate to high salinity areas and return to spawn several times.

4.4 Salmonid Habitat Requirements

Habitat supporting a species or a life stage of a species generally makes up only part of an ecosystem. This discussion focuses on defining those aspects of the lower Columbia River and estuary portion of the ecosystem that provide habitat for the listed fish species.

The quality or suitability of habitat meeting the needs of an organism of concern is determined by a variety of factors. These include the physical characteristics of the environment that are important to the organism, biological production yielding food sources for the organism, and populations of other organisms that are either competitors or predators

Water depth, water velocity, and substrate type are basic physical characteristics determining the suitability of the habitat for young and adult salmon. Water temperature, salinity and turbidity are secondary physical factors that influence the suitability of the habitat. Salmon appear to find relatively wide ranges acceptable for these secondary factors.

4.4.1 Physical Habitat Characteristics of Lower Columbia River Guilds

Each of the three guilds or groups of salmon moving through the lower Columbia River project area has substantially different habitat requirements. Ocean-type juveniles appear to have the most restrictive requirements for physical habitat characteristics. Stream-type juvenile salmon have somewhat less rigid habitat preferences. Adult salmon appear to be relatively none specific in the physical characteristics they are willing to accept. The following information on the habitat characteristics important to young salmon is derived primarily from Weitkamp (2001a) except where otherwise noted.

Ocean-Type Juvenile Salmon

Ocean-type subyearlings require specific physical characteristics in the habitat they commonly use. Apparently, because of their small size, they are unable or unwilling to use much of the habitat that larger juveniles find suitable.

Water Depth: These small fish are generally found within 1 meter of the water surface. Because they are shoreline oriented, this commonly means they occupy shallow water habitat with depths of 0.3 to 2 meters (1 to 7 feet).

Water Currents: The small ocean-type juveniles are not capable of dealing with substantial current velocities; consequently, they tend to occupy areas with current velocities of 9 centimeters per second (0.3 foot per second) or less.

Substrate Type: Subyearling salmon actually are found associated with a wide range of substrate types throughout their range, extending from mud flats to rock cliffs. However, because they are both strongly shoreline oriented and require weak current speeds to remain within the habitat, they are most frequently found in areas with fine grain substrates of silt and sand.

Salinity: Ocean-type juveniles occupy a substantial range of salinities. Although they all begin their rearing migration in freshwater, they appear to have the capacity to readily enter moderate to high salinity conditions within hours to a day. Wagner et al. (1969) found that all fall chinook alevins tested were able to tolerate 15 to 20 parts per thousand (ppt) salinity immediately following hatching. Ellis (1957) found ocean-type fall chinook fry (3 grams) adapted rapidly to high salinity, with high survival to adult returns after only 5 days of incremental adaptation to saltwater with 25 to 75 percent salinity (~ 9 to 25 ppt). Tiffan, et al. (2000) determined that once active migrant fall chinook passed McNary Dam, 470 kilometers upstream from the Columbia River's mouth, 90 percent of the subyearlings were able to survive challenge tests in 30 ppt seawater at 18.3°C. Clark and Shelbourn (1985) determined that very small chinook fry of 1.5 grams and larger could survive and grow in seawater.

Water Temperature: Subyearling salmon commonly experience a wide range of temperatures during their rearing migration through the lower Columbia and other rivers. Because these fish remain in shallow water and migrate in the spring through early summer, they are exposed to water with temperatures raised to near the upper end of their range. Tidal fluctuations cause water to flow over flats heated by the sun resulting in temperatures that frequently reach 15 to 20° C for brief periods, only to be replaced within hours by much cooler river or estuarine water. The lethal temperature for young salmon is about 22° C for fish acclimated to cold water (Brett, 1956; Lee and Rinne, 1980). These studies have shown that young salmon can survive substantially higher temperatures when acclimated to moderate temperatures (10 to 15°C), and can tolerate higher temperatures for brief periods of time (hours) (Brett, 1956; Elliott, 1981).

Sublethal effects can occur at temperatures well below lethal limits. Exposure to high but sublethal temperatures for prolonged periods can have a broad range of effects on various fish functions. Brett (1971) identified 25 physiological responses in sockeye. Two general response patterns have been identified. The response (e.g., standard metabolic rate, active heart rate, gastric evacuation) can either increase continuously with increased temperature, or the response (e.g., growth rate, swimming speed, feeding rate) can increase with temperature to maximum values at optimum temperatures and then decrease as temperature continues to increase (Brett, 1971; Elliott, 1981). At or near 22°C salmonids tend to cease feeding. Growth rates tend to be highest for salmonids between 10 and 18°C when adequate food rations are available. At lower food availability growth decreases at higher temperatures (Brett et al., 1969). At low food rations growth is very low or ceases at temperatures above about 15°C.

Turbidity: Turbidity and suspended sediment are a natural part of the habitat occupied by young and adult salmon. Although these two parameters are often used interchangeably, they refer to different properties. Turbidity refers to light attenuation by materials in the water, while suspended sediment refers to the amount of mineral particles suspended in the water column.

Turbidity at moderate levels of about 25 to 110 nephelometric turbidity units (NTUs) is common in rivers with migrating salmon. Turbidity can decrease predation on young salmonids. Gregory and Levings (1998) found that young salmon are less likely to be eaten by piscivorous fish at higher turbidities. Turbidity can also reduce the feeding efficiency of young salmonids. Gregory (1988) reported the reaction distance of young chinook to benthic prey decreased greatly between 0 and about 50 NTUs. However, from 50 to 250 NTUs there was little change in reaction distance, in part because the fish were only reacting to prey within about 8 cm at 50 NTUs. Berg and Northcote (1985) demonstrated a similar decrease in the reaction distance of juvenile coho to pelagic prey at turbidities of 30 and 60 NTUs as compared to zero NTU. Growth of young steelhead and coho was reduced by chronic turbidity in the range of 20 to 50 NTUs in freshwater rearing (Sigler et al., 1984). However, turbidity in the range of 30 to 60 NTUs is common in natural rivers such as the Columbia.

Direct survival of young salmonids can be affected at high suspended sediment loads. Noggle (1978) defined the lethal concentration 50 (LC₅₀) for turbidity (the amount expected to cause death in 50 percent of the exposed population) under summer conditions (the most sensitive) as near 1.2 grams per liter (g/L) for young coho. Smith (1978) determined the LC₅₀ for chum to be greater than 2.5 g/L.

In the lower Columbia River turbidity is important in relation to the zone of the turbidity maximum. Relatively high turbidity is a characteristic of the intermixing of fresh and saltwater where high biological productivity occurs. However, Jones et al. (1990) concluded that, in the lower Columbia River, the standing stocks of benthic infauna were highest in the protected tidal flat habitats, while those of epibenthic and zooplanktonic organisms were concentrated within the estuary mixing zone.

Stream-Type Juvenile Salmon

Because of their relatively large size and rapid migration, stream-type juveniles have somewhat different habitat requirements in the lower Columbia River and its estuary than the subyearlings. These relatively large smolts have the physical capacity to deal with a much larger range of conditions than the subyearlings.

Water Depth: These larger juveniles have been found over a substantial range of water depths although they appear to have some propensity to remain near the water surface. Because they are not shoreline-oriented, they are found throughout a substantial portion of the near-surface water column at depths of 0.3 to 10 meters.

Water Currents: The larger stream-type juveniles are capable of resisting substantially greater current velocities than subyearlings. They are found throughout a wide range of current speeds as they move downstream, generally avoiding low velocity areas except during brief periods when they tend to hold position against tidal or river currents.

Substrate Type: Salmon smolts generally are not associated with river or estuarine substrate types. Because they tend to be more water column oriented than the subyearlings, the smolts are found in areas having a wide range of substrate types.

Salinity: Stream-type juveniles commonly begin the process of smoltification prior to initiating their downstream migration. Salinity challenge tests have routinely shown they are capable of residing in

moderate to high salinities long before they reach the saline water of the estuary. Sims (1970) reported that young chinook in the Columbia River that were marked one day in a fresh water area were found the next day in a high salinity area 43 kilometers downstream. Even subyearling salmon migrating from upstream areas are generally able to tolerate immediate exposure to the high salinity conditions of sea-water challenge tests by the time they reach McNary Dam, far upstream from the estuary (Tiffan, et al., 2000).

Movement from fresh water to saline water apparently does not place high metabolic demands on young salmon. Bullivant (1961) found young chinook had no significant difference in oxygen consumption rates when in fresh water, dilute sea water, or sea water (35.4 ppt). He interpreted this lack of difference in oxygen consumption as an indication that the energy expended on osmoregulation was a small portion of the total energy consumption.

Water Temperature: These habitat characteristics are the same for the stream-type guild as for the ocean-type guild.

Turbidity: These habitat characteristics are the same for the stream-type guild as for the ocean-type guild.

Adult Salmonids

Adult salmon have much less restrictive habitat requirements as they migrate through estuarine and lower river areas as compared to juveniles.

High concentrations of suspended sediment can influence the homing of adult salmon. Whitman, et al. (1982) found adult chinook tended to avoid Mount St. Helens ash at about 650 milligrams per liter (mg/L), but ash at average concentrations of 3.4 g/L in the Toutle River did not appear to influence homing performance.

Generally adult salmon are not exposed to temperatures in a lethal range because of their capacity to avoid high temperatures together with their propensity to remain in relatively open water until they reach spawning areas. However, high temperatures can delay their migrations. In 1941, extremely high water temperatures (22 to 24° C) apparently resulted in chinook, sockeye and steelhead adults congregating in small cold streams near the Bonneville and Rock Island Dams (Fish and Hanavan, 1948). At the Okanogan River Major and Mighell (1967) observed that temperatures greater than 21°C blocked sockeye migrations, while stable or even rising temperatures below 21°C did not block migration.

Trout

Considerable information regarding trout habitat was previously presented to the Sustainable Ecosystems Institute (SEI) Science Panel by Doug Young (USFWS) during the initial workshop held in March 2001. Published and other information on cutthroat trout was recently assembled by Trotter (1989) and again for Appendix D-2 of this document. Previously Sumner (1962), Lowry (1965), and Giger (1972) have provided information on anadromous forms of cutthroat trout in Oregon coastal streams, although not the Columbia River. Likewise, available information on anadromous forms of bull trout comes primarily from areas other than the Columbia River. As stated above, the characteristics of habitat used by cutthroat trout and bull trout in estuarine areas are not well defined, but can be inferred from the available information.

Most likely the trout move relatively rapidly through the lower Columbia River to the estuary or ocean. Cutthroat trout generally make up a small portion of the salmonid collections that have been obtained in

the lower river, while char (bull trout/Dolly Varden) have been absent. Substantial numbers of adult cutthroat trout have been taken at times in relatively shallow water along shallow bars by sport fishers. Cutthroat have also been collected in the lower Columbia River at a number of estuarine locations (Loch, 1982) and just upstream from the estuary at Jones Beach (Dawley, 1985). Downstream migration of juvenile and adult cutthroat appears to occur in April and May, peaking in early May (Dawley, et al., 1979 and 1980). Johansen and Sims (1973) captured cutthroat in small numbers in purse seines in the channels of the lower river and estuary. Most of the trout were yearling fish collected in April to June.

In other areas, anadromous bull trout appear to move quickly through the lower river and estuarine areas during both smolt out migrations and adult spawning migrations based on their complete absence in most scientific collections. No information is available indicating holding, feeding, or other extended use of the lower Columbia River by either juvenile or returning adult bull trout. Anadromous bull trout most likely feed where forage fish are present, but not near the bottom in subtidal areas or near the shorelines, which do not provide habitat for forage fish. Anadromous bull trout have been found in Puget Sound in areas where Pacific herring, surf smelt, and Pacific sand lance spawn occur (Kraemer, 1994) apparently following concentrations of prey species.

Because bull trout are a relatively long-lived iteroparous species (spawn multiple times), the potential exists for the anadromous forms to make several outmigration and spawning runs through the lower Columbia River. Upstream migrations of bull trout spawners typically occur in early summer (late June and July) when water temperatures are relatively cool (Rieman and McIntyre, 1993), most likely in moderate to low velocity areas. Bull trout are not known to use shoreline habitat in the lower Columbia River.

4.4.2 Juvenile Salmonid Prey Resources

No information is available on prey resources historically used by young salmon before the substantial modification of the lower river and its estuary. Studies of the prey consumed by young salmon began long after the river system had become highly modified, providing information about how the system currently supports their survival, but not necessarily how it naturally supported their survival prior to modification.

Prey consumed by young salmon in the lower Columbia River with modified conditions and in other estuarine areas includes a variety of organisms (Table D4-2). As stated in Higgs, et al. (1995, p. 262), "...all Pacific salmon species are opportunistic in their food habits. Frequently, their daily diet consists of many food items. Moreover, prey selection is directed generally at the most commonly encountered species (available and abundant) that are organoleptically acceptable based on previous experience, visible, unable to escape readily, and of appropriate actual or perceived size relative to the size of the fish (Hyatt, 1979)."

In an early study of juvenile salmon food habits in the lower Columbia River, Craddock, et al. (1976) found they consume primarily insects in the spring and fall, while *Daphnia* is the major prey—selected more than other planktonic organisms—from July to October. Dawley et al. (1986) found that young salmon in the lower Columbia River consume diptera, hymenoptera, coleoptera, tricoptera, and ephemeroptera in the upstream portion of the area. Downstream their diet changes to diptera, cladocerans, and amphipods (*Corophium salmonis*, *Corophium spinicorne*, *Eogammarus confervicolus*). Many yearlings passing through the lower river were found by Dawley, et al. (1986) to have empty or less than full stomachs. Considerable overlap occurred in the diets of the salmon species, with dipterans being most important for coho. More recently, Bottom and Jones (1990) reported young chinook ate primarily *Corophium*, *Daphnia*, and insects, with *Corophium* being the dominant prey species in winter and spring, and *Daphnia* the dominant prey species in summer.

Corophium is commonly discussed as a primary prey item of juvenile salmon in the lower Columbia River. *Corophium salmonis* is a euryhaline species tolerating salinities in the range of 0-20 ppt (Holton and Higley, 1984). As shown by the above investigations, it is one of several major prey species consumed by juvenile chinook under existing conditions. Data from other estuaries indicates *Corophium* can be a substantial portion of the dietary intake for young salmon, but it is not included in most estuarine habitats. Data are not available that indicate its historic role in the diet of Columbia River salmon prior to substantial modification of the river system. *Corophium* may not be a highly desirable food source for young salmon. According to Higgs, et al. (1995), gammarid amphipods are high in chitin and ash and low in available protein and energy relative to daphnids and chironomid larvae. This may be in part why daphnids and chironomid larvae are commonly a major portion of the prey consumed by juvenile salmonids in the upper portions of estuaries where these organisms are generally available.

Table D3-2: Prey Consumed by Young Chinook in Estuarine Habitats (Weitkamp, 2001)

PREY CONSUMED	LOCATION	REFERENCE
Neomysis, Corophium, and insects	Sacramento-San Joaquin, CA	Sasaki, 1966
Primarily copepods, amphipods, and fish larvae within the inland delta.	Sacramento-San Joaquin, CA	Kjelson, et al., 1982
Insects in spring and fall. Daphnia is major prey, selected more than other planktonic organisms, from July to October.	Columbia R. OR-WA	Craddock, et al., 1976
Subyearlings at Jones Beach (Rkm 75) were in a feeding transition zone from insects (diptera, hymenoptera, coleoptera, tricoptera, ephemeroptera) upstream to diptera, cladocerans, and some amphipods (<i>Corophium salmonis</i> , <i>C. spinicorne</i> , <i>Eogammarus confervicolus</i>) downstream. Many yearlings passing through the estuary had empty or less than full stomachs. Considerable overlap of the salmon species occurred, with dipterans most important for coho.	Columbia R. OR-WA	Dawley, et al., 1986
Chinook ate <i>Daphnia</i> , <i>Corophium</i> and insects, with major prey being <i>Corophium</i> in winter and spring and <i>Daphnia</i> in summer.	Columbia R. OR-WA	Bottom and Jones, 1990
<i>Corophium</i> , gammarids, mysids, cumacea, crangonids, and crab predominant prey.	Chehalis R. WA	Herrmann, 1970
Insects, gammarids, and mysids consumed in constructed and natural sloughs (also coho). Lower stomach content fullness in constructed sloughs.	Chehalis R. WA	Miller and Simenstad, 1997
Fry fed almost exclusively on chironomid larvae in Capitol Lake until August, when they began to feed on <i>Daphnia</i> and <i>Epischura</i> .	Deschutes R. WA	Engstrom-Heg, 1968
Dipterans, gammarids, decapod larvae, calanoids, euphausiids, mysids, and fish.	Nisqually R. WA	Fresh, et al., 1978
Diptera, mysids and gammarids.	Nisqually R. WA	Pearce, et al., 1982
Copepods and harpacticoids in general area. Primarily crab larvae and gammarids in Hylebos waterway.	Commencement Bay, WA	Meyer, et al., 1981
Observed feeding under piers. Appeared to acquire less food than natural shorelines.	Commencement Bay, WA	Simenstad, et al., 1985
Ate crab larvae, and drift insects; ate chum and consumed harpacticoids in highly modified shorelines with little eelgrass or macrophytes.	Commencement Bay, WA	Simenstad, Cordell, et al., 1985
Tended to select chironomid larvae (epibenthic) in March-May in constructed wetlands, but ate few harpacticoids and nematodes although these were dominant in wetlands. In river fed on adults (neuston) as well as plecoptera, dipterans, <i>Daphnia</i> , <i>Corophium</i> , <i>Eogammarus</i> , and cyclopoids.	Puyallup R. WA	Shreffler, et al., 1992a

Gammarids, chironomids, and calanoids. Ate more marine prey at downstream locations. Near shorelines ate epibenthic. In deeper water ate pelagic prey.	Duwamish R. WA	Meyer, et al., 1980
Consumed insects, gammarid amphipods, cumacea, <i>Corophium</i> , and mysids (in order of numerical abundance); gammarids (28 percent), insects (27 percent), and fish (19 percent) were the most important by weight.	Snohomish R. WA	Conley, 1977
Chinook consumed fish larvae and gammarids along beaches, with some insects and cumacea. In deeper water they ate fish larvae, barnacle larvae, crab larvae, insects, and gammarids.	Snohomish R. WA	Parametrix, Inc., 1985
Fry consumed <i>Corophium</i> , harpacticoids, and insect larvae in marsh area.	Skagit R. WA	Congleton and Smith, 1976
Fed on copepods (50 percent) and chironomids (26 percent) eaten by fry (40-95 mm) in high saline waters.	San Juan Is. WA	Annan, 1958
Juvenile chinook and chum were found to prey on larval and juvenile baitfish.	Birch Bay Marina north Puget Sound WA	Cardwell, et al., 1980
Crab larvae, herring, sand lance larvae, and polychaetes eaten by smolts (118 mm) near shore. Offshore ate herring, euphausiids, gammarids, and mysids.	Puget Sound,	Fresh, et al., 1981
Chinook preferred euphausiids along with fish in spring, and crab larvae and fish during the summer. During fall they ate a variety of euphausiids, amphipods, crab larvae, and fish. Offshore, chinook, chum, and coho juveniles preyed on the same food sources with different preferences.	Puget Sound	Beamish, et al., 1998
Ate pelagic prey, insects, calanoids, juvenile fish, and polychaetes in August.	San Juan beaches, WA	Simenstad, et al., 1977
Ate primarily adult insects, cumacea, and <i>Neomysis</i> . Dominant organisms varied with time of day on Fraser R. tide flat.	Fraser R. BC	Levings, 1982
Ate chironomids, cladocera, <i>Anisogammarus</i> , <i>Corophium</i> , <i>Neomysis</i> , and insects.	Fraser R. BC	Dunford, 1975
Ate harpacticoids, chironomids, adult insects, and amphipods. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders.	Fraser R. BC	Healey, 1980b
At Nanaimo, fed mainly on decapod larvae, mysids, and adult insects in the inner estuary, and larval herring in the outer estuary (1978, 1979). In 1972 their diet included more amphipods and harpacticoids. At Nitinat, fed primarily on adult insects, gammarids, and crab larvae, and occasionally on cladocera; showed seasonal shift in prey items with cladocera and fish larvae becoming important later in migration period.	Fraser R. BC Nanaimo R. BC Nitinat R. BC	Healey, 1982b
Large fry (57 to 69 mm) fed on epibenthic prey at low rates in high turbidity (370 to 810 NTU) and clear water, and at highest rates in intermediate turbidity (18 to 150 NTU) present in tidal channels). Small fry (49 to 50 mm) fed at highest rates in low turbidity; planktonic prey consumed at highest rates in low turbidity for both sizes.	Fraser R. BC laboratory	Gregory, 1994
Harpacticoids important prey in March-early April, decapod larvae and amphipods in April-May, and mysids and insects in May-July. Ate fish as they moved offshore. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders.	Nanaimo R. Vancouver Is, BC	Healey, 1980b
Fed on <i>Anisogammarus</i> found in periphyton on logs and near bank substrates in Inlet having steep intertidal. Also fed on chironomids when nearshore, but fish larvae, euphausiids, decapod larvae, copepods, cladocerans, chaetognaths, barnacle	Somas R., Alberni Inlet, Vancouver Is. BC	Kask and Parker, 1972

larvae, polychaete larvae, and cephalopods when in open water.

Fed on zooplankton, not harpacticoids. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders .

Nitinat R. BC

Healey, 1980b

Ate benthic estuarine organisms along with fish in estuary in March-May, and primarily juvenile herring during July-September, along with decapod larvae.

Cowichan R. BC

Argue, et al., 1985

Ate *Anisogammarus* and *Neomysis ragii*, plus benthic invertebrates (chum and coho ate same).

Squamish R, BC

Goodman and Vroom, 1972

Neomysis and insects (June-July).

Squamish R, BC

Levy and Levings, 1978

Wild chinook consumed *Bosmina* and insects, shifted to *Neocalanus* & *Cumella* at outer estuary locations (chum same).

Campbell R. BC

MacDonald, et al., 1986

Adult salmon have generally ceased feeding by the time they enter estuarine areas. Chinook, sockeye, and steelhead have acquired food reserves in the ocean environment that sustain them through their migration according to Burgner (1991). "Salmon usually cease feeding before entering their natal streams and depend on their energy reserves for migration, maturation of gonads, spawning, and redd (nest) defense until death."

Only one investigation of the estuarine prey eaten by bull trout was identified. Narver and Dahlberg (1965) found that juvenile bull trout ate predominantly on Pacific sand lance, caplin, greenling, sculpin, and juvenile sockeye, together with Gammarus and euphausiids. Feeding by cutthroat trout and bull trout during their upstream migration through the lower river has not been defined. It is likely these fish continue to feed to some degree as they commonly retain a functional digestive system and return to saltwater following spawning.

4.4.3 Time Present in Project Area

Subyearlings

Chinook and chum fry from the lower Columbia spawning areas appear in the project area by late March. Most likely chum and the early chinook rear in the project area through late April or early June, based on the residence time of these fry in other Pacific Northwest estuaries (Weitkamp, 2001).

Yearling Smolts

Chinook, sockeye, and steelhead smolts (second to third year of life) migrate through the project area primarily from April through August.

Adults

Adult salmonids are present in the project area throughout much of the year. Generally upstream migration begins with spring chinook migrating to upstream portions of the watershed in March or April. These early chinook are followed by summer and fall run chinook that form a nearly continuous run of upstream migrants through September.

Trout

Downstream migration of juvenile and adult cutthroat appears to occur in April and May, peaking in early May (Dawley et al., 1979 and 1980). Johansen and Sims (1973) captured cutthroat in small numbers in purse seines in the channels of the lower Columbia River and estuary. Most of the trout were yearling fish collected in April to June.

Upstream migrations of bull trout spawners typically occur in early summer (late June and July) when water temperatures are relatively cool (Rieman and McIntyre, 1993), most likely in moderate to low velocity areas.

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